APPLICATION

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TITLE: **MULTICHANNEL FILTER FOR OUTDOOR HANDHELD ULTRA WIDEBAND COMMUNICATIONS**

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MULTICHANNEL FILTER FOR OUTDOOR HANDHELD ULTRA WIDEBAND COMMUNICATIONS

Background

This invention is generally relative to wireless handheld ultra wideband communications for outdoor operation.

On April 22, 2002, U.S. Federal Communications Commission (FCC) released the revision of Part 15 of the Commission's rules regarding ultra-wideband (UWB) transmission systems to permit the marketing and operation of certain types of new products incorporating UWB technology. With appropriate technology, UWB device can operate using spectrum occupied by existing radio service without causing interference, thereby permitting scare spectrum resources to be used more efficiently. It has been known that UWB technology offers significant benefits for Government, public safety, businesses and consumers under an unlicensed basis of operation spectrum.

UWB device can be classified in three types based on the operating restrictions: (1) imaging system including ground penetrating radars and wall, through-wall, surveillance, and medical imaging device, (2) vehicular radar systems, and (3) communications and measurement systems. In general, FCC is adapting unwanted emission limits for UWB device that are significantly more stringent than those imposed on other Part 15 devices. In other words, FCC limits outdoor use of UWB device to imaging

systems, vehicular radar systems and handheld devices. Limiting the frequency band, which is based on the -10 dB bandwidth of the UWB emission, within certain UWB products will be permitted to operate.

The outdoor handheld UWB systems are intended to operate in a peer-to-peer mode without restriction on location. The handheld UWB device must operate in the frequency band from 3.1 GHz to 10.6 GHz, with an extremely conservative out of band emission mask to address interference with other devices. The handheld UWB devices are permitted to emit at or below the Part 15.209 limit in the frequency band below 960 MHz. The emissions above 960 MHz must conform to the following emissions mask as shown in Table 1:

Table 1

Frequency (MHz)	EIRP (dBm)
0-960	-41.3
960-1610	-75.3
1610-1900	-63.3
1900-3100	-61.3
3100-10600	-41.3
Above 10600	-61.3

FCC proposed to define a UWB device as any device where the fractional bandwidth is greater than 0.25 based on the formula as follows:

$$FB = 2\left(\frac{f_H - f_L}{f_H + f_L}\right), \quad (1)$$

where f_H is the upper frequency of the -10 dB emission point and f_L is the lower frequency of the -10 dB emission point. The center frequency of the UWB transmission is defined as the average of the upper and lower -10 dB points. That is

$$F_C = \frac{f_H - f_L}{2}. \quad (2)$$

In addition, a minimum frequency bandwidth of 500 MHz must be used for UWB device regardless of center frequency.

Given an entire frequency bandwidth of 7.5 GHz (3.1-10.6 GHz), it is difficult to design the transmitter and/or receiver device for a single UWB signal that occupies the entire frequency bandwidth from 3.1 GHz to 10.6 GHz directly. This is because we need to have a very-high A/D and D/A converter as well as high-speed circuits and digital signal processors to operate the UWB device for the wireless communications. As a result, cost of such a UWB device could be very expense. In addition, interference between the UWB and other device, such as WLAN 802.11a device, can be occurred because the WLAN 802.11a device operates in the lower frequency range from 5.15 GHz to 5.35 GHz or in the upper frequency range from 5.725 GHz to 5.825 GHz. Moreover, the UWB device may not be able to transmission of data with scalability.

Due to the proliferation of 7.5 GHz UWB for wireless broadband communications, it would be desirable to have a new technology of developing one multichannel UWB solution, to reduce the interference with the WLAN 802.11a device and to transmit and receive the transmission data rate with scalability as well as to reduce the cost for outdoor handheld UWB transceiver. The multichannel UWB solution highly depends on a multichannel filter, which must meet the FCC request of the outdoor emission limitation, to provide the multichannel-based multi-carrier modulation. Therefore, in this embodiment, the multichannel filter for outdoor handheld ultra wideband communication is invented for wireless broadband communications.

Thus, there is a continuing need of the multichannel filter for outdoor handheld UWB transceiver that enables a user to transmit the data rate with programmability and scalability and avoid the interference with WLAN 802.11a device.

Brief Description of the Drawings

FIG. 1 shows a block diagram of showing one embodiment of a multichannel filter-based outdoor handheld UWB communication system in accordance with the present invention.

FIG. 2 is a block diagram of showing multichannel filter-based UWB transmitter of outdoor handheld UWB transceiver according to some embodiments.

FIG. 3 is a block diagram of showing multichannel filter-based UWB receiver of outdoor handheld UWB transceiver according to some embodiments.

FIG. 4 is a transmitter spectrum mark of an outdoor power spectral density according to some embodiments.

FIG. 5 is a frequency and impulse response of a digital FIR lowpass-shaping filter for use in the transmitter and/or receiver according to one embodiment.

FIG. 6 is a frequency spectrum of 11 multichannel spectrums and outdoor FCC emission limit according to some embodiments.

FIG. 7 is a block diagram of showing a digital cascaded FIR filter including a digital multiband FIR lowpass shaping filter and digital FIR rejected lowpass filter according to one embodiment.

FIG. 8 is an enlarged transmitter spectrum mark of the outdoor power spectral density according to some embodiments.

FIG. 9 is a frequency and impulse response of digital enlarged FIR lowpass shaping filter for use in the transmitter and/or receiver according to one embodiment.

FIG. 10 is a frequency response of digital multiband FIR lowpass shaping filter with image response for use in the transmitter and/or receiver according to one embodiment.

FIG. 11 is a rejected transmitter image spectrum mark of the outdoor power spectral density according to some embodiments.

FIG. 12 is a frequency and impulse response of digital FIR rejected filter to eliminate the image response for use in the transmitter and/or receiver according to one embodiment.

FIG. 13 is a frequency response of digital cascaded FIR filter of combining the digital multiband FIR lowpass shaping filter and the digital FIR rejected filter.

FIG. 14 is a frequency spectrum of 11 multichannel spectrums using the digital FIR cascaded filter and the outdoor FCC outdoor emission limit according to some embodiments.

FIG. 15 is a frequency spectrum including 10-multichannel spectrums (without the forth channel) and the outdoor FCC emission limit according to some embodiments.

FIG. 16 is a frequency spectrum including 10-multichannel spectrums (without the fifth channel) and the outdoor FCC emission limit according to some embodiments.

FIG. 17 is a frequency spectrum including 9-multichannel spectrums (without the fourth and fifth channel) and the outdoor FCC emission limit according to some embodiments.

Detailed Description

Some embodiments described herein are directed to a multichannel filter-based handheld UWB communications for outdoor operation. The outdoor handheld UWB communication system may be implemented in hardware, such as in an Application Specific Integrated Circuits (ASIC), digital signal processor, field programmable gate array (FPGA), software, or a combination of hardware and software.

A multichannel filter-based handheld UWB communication transceiver 100 for outdoor operations is shown in FIG. 1 in accordance with one embodiment of the present invention. This outdoor handheld UWB transceiver 100 contains a UWB multi-carrier and multichannel RF section 114 that receives and/or transmits multichannel-based UWB signals from an antenna 110 or to an antenna 112. The section 114 is coupled to an analog and digital interface section 116 that includes A/D and D/A converters. The interface section 116 is also connected with a digital baseband processing section 118 that implements multichannel digital filtering, rake processing, spread and de-spread processing, interleaver and de-interleaver, and code and de-code processing. The digital baseband processing section 118 has an interface with a UWB network interface section 120, which is coupled to a UWB network 122. In accordance with one embodiment of the present invention, the UWB communication transceiver 100 is used for the outdoor

handheld UWB communications that can both transmit and receive speech, audio, images and video and data information with programmability and scalability.

The handheld UWB communication transceiver 100 can transmit and/or receive the UWB signals by using one single channel and/or up to 11-multichannel. Each channel has a frequency bandwidth of 650 MHz. The UWB transceiver 100 can transmit 40.625 Msps with a single channel. A total of 11-multichannel can allow the UWB transceiver 100 to transmit 446.875 Msps in parallels. With 16 PN spread sequence codes for each symbol, the UWB transceiver 100 can transmit 650 Mcps within each channel. As a result, the handheld UWB communication transceiver 100 can transmit and/or the chip data rate up to 7.150 Gcps for the outdoor operation.

FIG. 2 is a block diagram of showing multichannel filter-based UWB transmitter 200 of the outdoor handheld UWB transceiver according to some embodiments. The UWB transmitter 200 receives user data bits 210 with information data rate of 223.4375 Mbps. The information data bits 210 are passed through a 1/2-rate convolution encoder 212 that may produce a double data rate of 446.875 Msps by adding redundancy bits. The symbol data is then interleaved by using a block interleaver 214. Thus, the output symbols of the block interleaver 214 are formed the 11-multichannel UWB signal by using a multichannel PN sequence mapping 218. Each channel has the symbol data rate

of 40.625 Msps. The multichannel PN sequence mapping 218 is to perform spreading for each channel symbol data with 16 orthogonal spread sequence chips and to produce 650 Mcps for each channel under a multichannel control 230. A PN sequence look-up table 216 provides the unique orthogonal sequences for each channel spreading. Then each channel symbol data are sequentially passed through a digital FIR shaping filter system 220 to limit the frequency bandwidth of UWB signal with 650 MHz for each channel transmission. Each channel signal is then passed through a D/A converter 222. The output chip data of each channel from the D/A converter 222 is thus modulated with a multi-carrier by using a multichannel based multi-carrier modulator 224. Then, the output analog signals of the multichannel-based multi-carrier modulator 224 are passed to the power amplifier (PA) 226 through an antenna into air.

FIG. 3 is a block diagram of showing a multichannel filter-based outdoor handheld UWB receiver 300 according to some embodiments. A low noise amplifier (LNA) 310 that is connected with a multichannel-based multi-carrier down converter 312 receives the UWB signals from an antenna. The output of the LNA 310 is passed through the multichannel-based multi-carrier down converter 312 to produce the baseband signal for an A/D converter 314. A multichannel control 320 and synchronization and time control 318 restrain the multichannel-based multi-carrier down

converter 312. The bandlimited UWB analog signals are then sampled and quantized by using the A/D converter 314, with the sampling rate at ≥ 650 MHz. The digital signals of the output of the A/D converter 314 are filtered by using a digital FIR receiver lowpass filter 316 to remove the out of band signals with controlling from the synchronization and time control 318. The output data from the digital FIR receiver lowpass filter 316 is used for a rake receiver 324. The channel estimator 322 is used to estimate the channel phase and frequency that are passed into the rake receiver 324. The rake receiver 324 calculates the correlation between the received UWB signals and the channel spread sequences, which are provided by using the PN sequence look-up table 332, and performs coherent combination. The output of the rake receiver 324 is passed to an equalizer 326, which also receives the information from the channel estimator 322, to eliminate inter-symbol interference (ISI) and inter-channel interference (ICI). Then, the output of the equalizer 326 produces the signals for a de-spreading of PN sequence and de-mapping 328 to form the UWB signals of symbol rate at 446.875 Msps. The symbol data is de-interleaved by using a block de-interleaver 330. Thus, the output data of the block de-interleaver 330 is used for the Viterbi decoder 334 to decode the encoded data and to produce the information data bits at 223.4375 Mbps.

FIG. 4 is a transmitter spectrum mark 420 of the outdoor power spectral density 400 for the use in the each channel filter according to some embodiments. The magnitudes (dBm) of the frequency response with an error of $\pm\delta_i$ (i = 1,2,3,4) for corresponding frequencies (GHz) are given by,

$$(-41.8-\delta_1) \le |H(f)| \le (-41.8+\delta_1)\,, \quad |f-f_c| \le 0.26\,, \qquad (3)$$

$$|H(f)| \le (-61.8+\delta_2)\,, \quad |f-f_c| = 0.325\,, \qquad (4)$$

$$|H(f)| \le (-63.8+\delta_3)\,, \quad |f-f_c| = 0.39\,, \qquad (5)$$

$$|H(f)| \le (-75.8+\delta_4)\,, \quad 0.45 \le |f-f_c| \le 0.5\,. \qquad (6)$$

The transmitter spectrum mark 420 serves as a rule for designing a digital FIR lowpass-shaping transmitter and/or receiver filters.

Referring to FIG. 5 is a frequency response (dBm) 510 and impulse response 520 of digital FIR lowpass-shaping transmitter and/or receiver filter 500 based on the transmitter spectrum mask 420 in FIG. 4 for the use in each channel according to one embodiment. The result of designing the digital FIR lowpass-shaping filter 520 does meet the requirements of the transmitter spectrum mask 420 of the outdoor power spectrum density 400 as defined in FIG. 4. The sampling frequency rate F_s of this filter is 2 GHz. This impulse response 520 of the digital FIR lowpass-shaping filter is an odd symmetric with a total of 83

filter coefficients. Table 2 lists all the filter coefficients of the digital FIR lowpass-shaping filter.

Table 2

Coefficients	Value	Coefficients	Value
h[0]	7.6488735705936605e-005	h[-21],h[21]	-9.9696474129624093e-007
h[-1],h[1]	6.2636205884599369e-005	h[-22],h[22]	6.8001098631267257e-007
h[-2],h[2]	3.8360738472336015e-005	h[-23],h[23]	1.6055470083229580e-006
h[-3],h[3]	1.1315222826039952e-005	h[-24],h[24]	1.3544197859980424e-006
h[-4],h[4]	-7.5438087863256088e-006	h[-25],h[25]	2.8906713844065611e-007
h[-5],h[5]	-1.3715350107903802e-005	h[-26],h[26]	-7.7640460252440758e-007
h[-6],h[6]	-9.6549464333329795e-006	h[-27],h[27]	-1.1590268443143087e-006
h[-7],h[7]	-1.4025569435129311e-006	h[-28],h[28]	-7.2082016980864959e-007
h[-8],h[8]	5.3003810907673923e-006	h[-29],h[29]	1.0449113646872343e-007
h[-9],h[9]	7.2459334117828691e-006	h[-30],h[30]	7.0581527869524552e-007
h[-10],h[10]	4.3825454945279616e-006	h[-31],h[31]	7.2894825863413297e-007
h[-11],h[11]	-7.3762240948801741e-007	h[-32],h[32]	2.7772069871654161e-007
h[-12],h[12]	-4.5458747488001017e-006	h[-33],h[33]	-2.5824128353050490e-007
h[-13],h[13]	-4.7131566336279298e-006	h[-34],h[34]	-5.0913724964550914e-007
h[-14],h[14]	-1.6403017957724223e-006	h[-35],h[35]	-3.7669532172385286e-007
h[-15],h[15]	2.0411082705529443e-006	h[-36],h[36]	-3.2564239303970273e-008
h[-16],h[16]	3.6642171169389545e-006	h[-37],h[37]	2.4370835675220430e-007
h[-17],h[17]	2.4832733363889074e-006	h[-38],h[38]	2.9201867311458947e-007
h[-18],h[18]	-1.2626402560439206e-007	h[-39],h[39]	1.4137476178313894e-007
h[-19],h[19]	-2.1121354877069656e-006	h[-40],h[40]	-5.5504489846808052e-008
h[-20],h[20]	-2.3106300667210457e-006	h[-41],h[41]	-1.7766983155229356e-007

The digital FIR lowpass-shaping filter may be designed using the least square method with weighting function for each frequency band. Other techniques such as equiripple approximations and windowing may also be used.

The implementation output *y[n]* of the digital FIR lowpass-shaping filter with 83 odd symmetric coefficients can be expressed as,

$$y[n] = \sum_{k=0}^{82} h[n]x[n-k], \qquad (7)$$

where *h[n]* is a set of the digital FIR lowpass-shaping filter coefficients as shown in Table 2 and *x[n]* is the digital input signal. Since the digital FIR lowpass-shaping filter 520 is odd symmetric coefficients, the above equation (7) can be rewritten as

$$y[n] = \sum_{k=0}^{40} h[n]\left(x[n-k] + x[n-82+k]\right) + h[42]x[n-42]\,. \qquad (8)$$

The equation (8) can be implemented with saving half taps of the computation. The computation complexity of implementing this digital FIR lowpass-shaping filter in equation (8) is 42 multiplications and 82 additions.

Referring to FIG. 6, which is an output of a multichannel spectrum (dBm) with multi-carrier frequencies 600 including 11-transmitter channel spectrums 620A-620K and the outdoor FCC emission limitation 610 according to some embodiments. Each channel frequency bandwidth is 650 MHz with different carrier frequencies, and is fitted under the outdoor FCC emission limitation 610. The detail positions of each transmitter channel spectrums (dBm) along with the center, lower and upper frequencies (GHz) as well as channel frequency bandwidth (MHz) are listed in Table 3.

Table 3

Label of the channel frequency spectrums	Center Frequency (GHz)	Lower Frequency (GHz)	Upper Frequency (GHz)	Frequency Bandwidth (MHz)
962A	3.45	3.125	3.775	650
962B	4.10	3.775	4.425	650
962C	4.75	4.425	5.075	650
962D	5.40	5.075	5.725	650
962E	6.05	5.725	6.375	650
962F	6.70	6.375	7.025	650
962G	7.35	7.025	7.675	650
962H	8.00	7.675	8.325	650
962I	8.65	8.325	8.975	650
962J	9.30	8.975	9.625	650
962K	9.95	9.625	10.275	650

In order to reduce the number of filter taps for the digital FIR lowpass shaping transmitter filter, an efficient design method 700 of the two cascaded filters may be used as shown in FIG 7. The first filter 710 is referred to as the digital multiband lowpass-shaping filter. The second filter 720 is called as the digital rejected lowpass filter. The combinations of the first digital FIR lowpass-shaping filter 710 and the second digital rejected lowpass filter 720 meet the frequency spectrum requirement of the transmitter spectrum mark 420 of the outdoor power spectrum density 400 as shown in FIG. 4.

Referring to FIG. 8, which is an enlarged transmitter spectrum mark 820 of the power spectral density 800 for the use of the digital multiband lowpass-shaping filter 710 according to some embodiments. The enlarged transmitter spectrum mark 820 is a double frequency bandwidth of the transmitter spectrum mask 420 of the outdoor power spectrum density 400 as shown in FIG. 4. The magnitudes (dBm) of the frequency response with an error of $\pm\delta_i$ (i = 1,2,3,4) for corresponding frequencies (GHz) are given by,

$$(-41.8-\delta_1) \leq |H(f)| \leq (-41.8+\delta_1), \quad |f-f_c| \leq 0.512, \qquad (3)$$

$$|H(f)| \leq (-61.8+\delta_2), \quad |f-f_c| = 0.65, \qquad (4)$$

$$|H(f)| \leq (-63.8+\delta_3), \quad |f-f_c| = 0.78, \qquad (5)$$

$$|H(f)| \leq (-75.8+\delta_4), \quad 0.9 \leq |f-f_c| \leq 1.0. \qquad (6)$$

The enlarged transmitter spectrum mark 820 serves as a rule for designing a digital multiband lowpass-shaping transmitter filter for the multichannel modulation.

Referring to FIG. 9 is a frequency response (dBm) 910 and impulse response 920 of the digital enlarged lowpass-shaping transmitter 900 based on the enlarged transmitter spectrum mask 820 of the power spectrum density 800 in FIG. 8 according to one embodiment. This impulse response 920 of the digital enlarged lowpass-shaping filter is an odd symmetric with a total of 51 filter coefficients. Table 4 lists all the enlarged filter coefficients.

Table 4

Coefficients	Value	Coefficients	Value
h[0]	1.4905382621261000e-004	h[-13],h[13]	-1.0335732862655074e-006
h[-1],h[1]	7.6680648491640600e-005	h[-14],h[14]	-2.2027524428255945e-006
h[-2],h[2]	-1.5178410889857596e-005	h[-15],h[15]	1.1349107902073455e-006
h[-3],h[3]	-1.9246816367394734e-005	h[-16],h[16]	1.5322309394969939e-006
h[-4],h[4]	1.0575089944159355e-005	h[-17],h[17]	-1.1207672214842861e-006
h[-5],h[5]	8.8048715073563623e-006	h[-18],h[18]	-1.0179971177063034e-006
h[-6],h[6]	-9.0052188618312217e-006	h[-19],h[19]	9.9455220021528296e-007
h[-7],h[7]	-3.4989976830573730e-006	h[-20],h[20]	7.1533195938216734e-007
h[-8],h[8]	7.2999338857814008e-006	h[-21],h[21]	-8.7419141944548621e-007
h[-9],h[9]	1.3688399180492002e-007	h[-22],h[22]	-5.5965129818442147e-007
h[-10],h[10]	-4.7454858992689909e-006	h[-23],h[23]	9.0256580368692782e-007
h[-11],h[11]	8.2887506682015732e-007	h[-24],h[24]	2.8080835334095955e-007
h[-12],h[12]	3.1263713712333295e-006	h[-25],h[25]	-7.3657896684832648e-007

Referring to FIG. 10 is a frequency response (dBm) 1010 of the digital multiband lowpass-shaping transmitter filter according to some embodiments. The center frequency band shaping of the frequency response 1010 meets the requirement the transmitter spectrum mark 420 of the power spectrum density 400 as shown in FIG. 4. This digital multiband lowpass-shaping filter has a symmetry image band that is created by inserting one zero into in the between of every two filter coefficients of the digital enlarged lowpass shaping filter. In other words, the digital multiband lowpass-shaping filter 1010 has 51 filter taps and 50 zeros. Since the filter does not need to implement the zero coefficients. As a result, the computation

complexity of implementing this digital multiband lowpass-shaping filter 1010 is 26 multiplications and 50 additions.

FIG. 11 is a rejected transmitter image spectrum mark 1120 of the power spectral density 1100 for the use to eliminate the image bands of the digital multiband lowpass-shaping filter 1010 according to some embodiments. The magnitudes (dBm) of the frequency response with an error of $\pm\delta_i$ $(i = 1,2)$ for corresponding frequencies (GHz) are given by,

$$(30.0-\delta_1)\le|H(f)|\le(30+\delta_1), \qquad |f-f_c|\le 0.28, \qquad (3)$$

$$|H(f)|\le(-18.3+\delta_2), \qquad 0.7\le|f-f_c|\le 1. \qquad (6)$$

The rejected transmitter image spectrum mark 1120 serves as a rule for designing a second digital rejected lowpass filter 720 as shown in FIG. 7.

Referring to FIG. 12 is a frequency response 1210 and impulse response 1220 of the digital rejected lowpass filter according to some embodiments. This digital filter is even symmetric with 10 filter coefficients. The computation complexity of this digital filter is 5 multiplications and 9 additions. Table 5 lists all the filter coefficients of the digital rejected lowpass filter.

Table 5

Coefficients	Value	Coefficients	Value
h[-1],h[1]	4.4130491021078377e-001	h[-4],h[4]	-3.3159624664790568e-002
h[-2],h[2]	1.3499284445782986e-001	h[-5],h[5]	1.2925496194348735e-002
h[-3],h[3]	-6.2314200832043407e-002		

Now referring to FIG. 13 is a frequency response of the digital cascaded FIR filter 1310 by combining the digital multiband lowpass-shaping filter 1010 and the digital rejected lowpass filter 1210. The result of this digital cascaded FIR filter 1310 exactly meet the requirement of the transmitter spectrum mask 420 of the power spectrum density 400 in FIG. 4.

The digital cascaded FIR filter 1310 of the digital multiband lowpass-shaping filter 1010 and the digital rejected lowpass filter 1210 has a total of 28 multiplications and 53 additions. Comparing with the single digital FIR lowpass-shaping filter 510, the digital cascaded FIR filter 1310 can save the computation complexity up to 41.67% of the multiplications and 43.62% additions. This leads to save the processing power, memory, and silicon area for the multichannel filter-based outdoor handheld UWB communication device.

Referring to FIG. 14 is an output of multichannel frequency spectrums (dBm) 1400 with multi-carriers, which are generated by using the digital cascaded FIR filter 1310, including 11-transmitter channel spectrums 1420A-1420K along with the outdoor FCC emission limitation 610 according to some embodiments. Each channel frequency bandwidth is 650 MHz with different carrier frequencies, and is fitted under the outdoor FCC emission limitation 610.

Referring to FIG. 15 is an output of multichannel frequency spectrums 1500 with multi-carriers including 10-transmitter channel spectrums 152064A-1520C, 1520E-1520K, along with the outdoor FCC emission limitation 610 according to some embodiments. There does not exist the fourth channel with frequency range from 5.075 GHz to 5.725 GHz in the frequency spectrums 1500. By no transmitting the fourth channel, the interference between the outdoor handheld UWB communication devices and WLAN 802.11a lower band can be avoided since the WLAN 802.11a lower band is in the frequency range from 5.15 GHz to 5.35 GHz, thereby resulting in coexistences.

Referring to FIG. 16 is an output of multichannel frequency spectrums 1600 with multi-carriers including 10 transmitter channel spectrums 1620A-1620D, 1620F-1620K, along with the outdoor FCC emission limitation 610 according to some embodiments. There is not the fifth channel with frequency range from 5.725 GHz to 6.375 GHz in the frequency spectrums 1600. By no transmitting the fifth channel, the interference between the outdoors handheld UWB communication devices and WLAN 802.11a upper band can be eliminated. This is because the WLAN 802.11a upper band is in the frequency range from 5.725 GHz to 5.825 GHz, thereby resulting in UWB and WLAN 802.11a coexistences.

Now referring to FIG. 17 is an output of multichannel frequency spectrums 1700 with multi-carriers including 9-